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(54) **HYDRAULIC SYSTEM OF CONSTRUCTION MACHINE**

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(58) **Field of Classification Search**
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See application file for complete search history.

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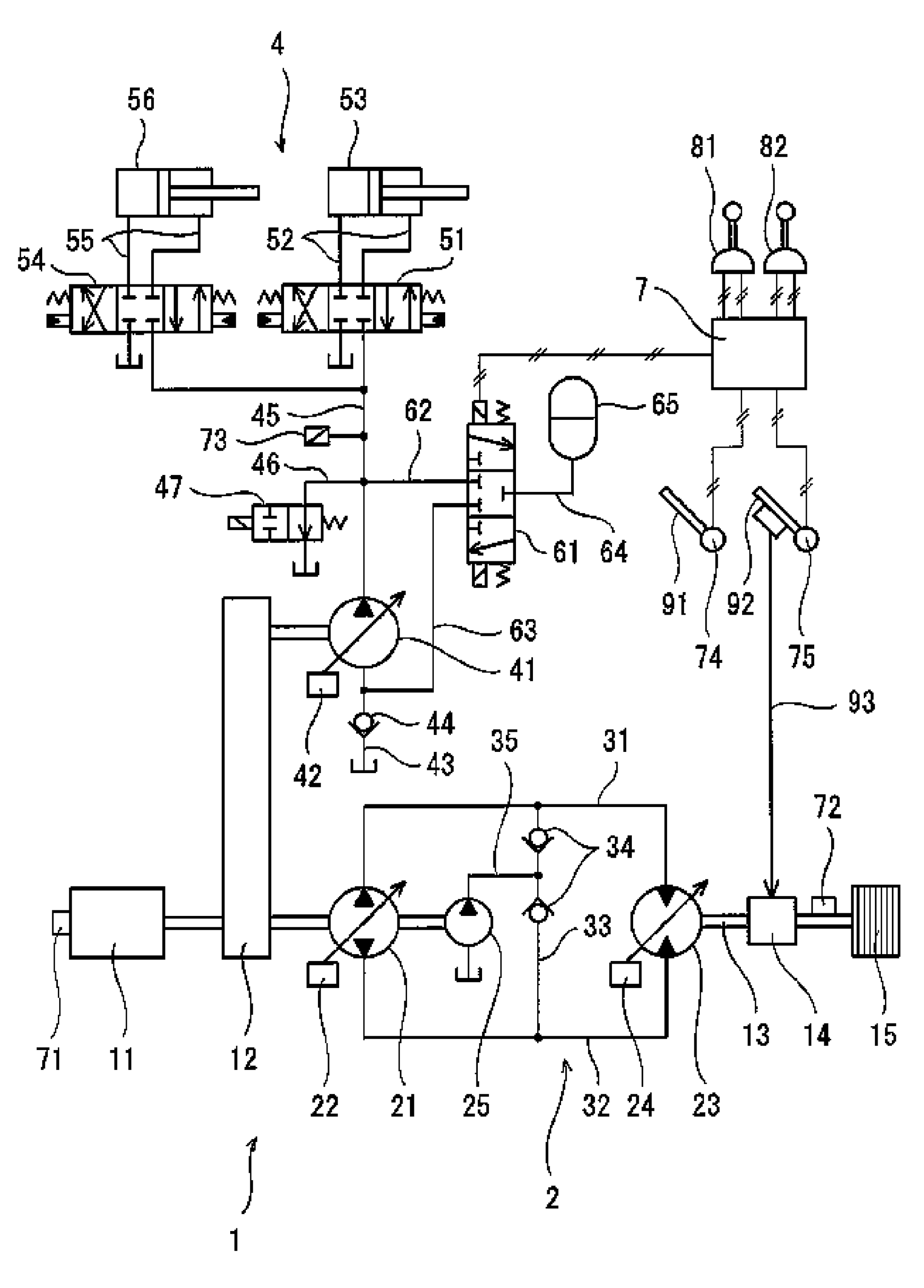
(57) **ABSTRACT**

A hydraulic system includes: a travel motor; travel pump connected to the travel motor, the travel pump driven by an engine; a work pump that sucks hydraulic oil from a tank through a suction line, and supplies the oil to a work hydraulic actuator through a delivery line, the work pump driven by the engine; a switching valve connected to the delivery line, and connected to a part of the suction line downstream of the check valve; and an accumulator connected to the switching valve. The switching valve switches between a neutral position in which the switching valve blocks a pressure accumulation line, a pressure release line, and the relay line, the pressure accumulation position in which the switching valve wherein the pressure accumulation line communicates with the relay line, a pressure release position in which the switching valve brings the relay line into communication with the pressure release line.

9 Claims, 6 Drawing Sheets



(51) **Int. Cl.**

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F15B 1/033	(2006.01)
F16H 61/40	(2010.01)
F16H 61/4096	(2010.01)
F16H 61/4157	(2010.01)
F16H 61/431	(2010.01)

(52) **U.S. Cl.**

CPC ***F15B 1/024*** (2013.01); ***F15B 1/033*** (2013.01); ***F15B 21/14*** (2013.01); ***F16H 61/40*** (2013.01); *E02F 9/2235* (2013.01); *E02F 9/2267* (2013.01); *E02F 9/2292* (2013.01); *F15B 2211/20576* (2013.01); *F16H 61/4096* (2013.01); *F16H 61/4157* (2013.01); *F16H 61/431* (2013.01)

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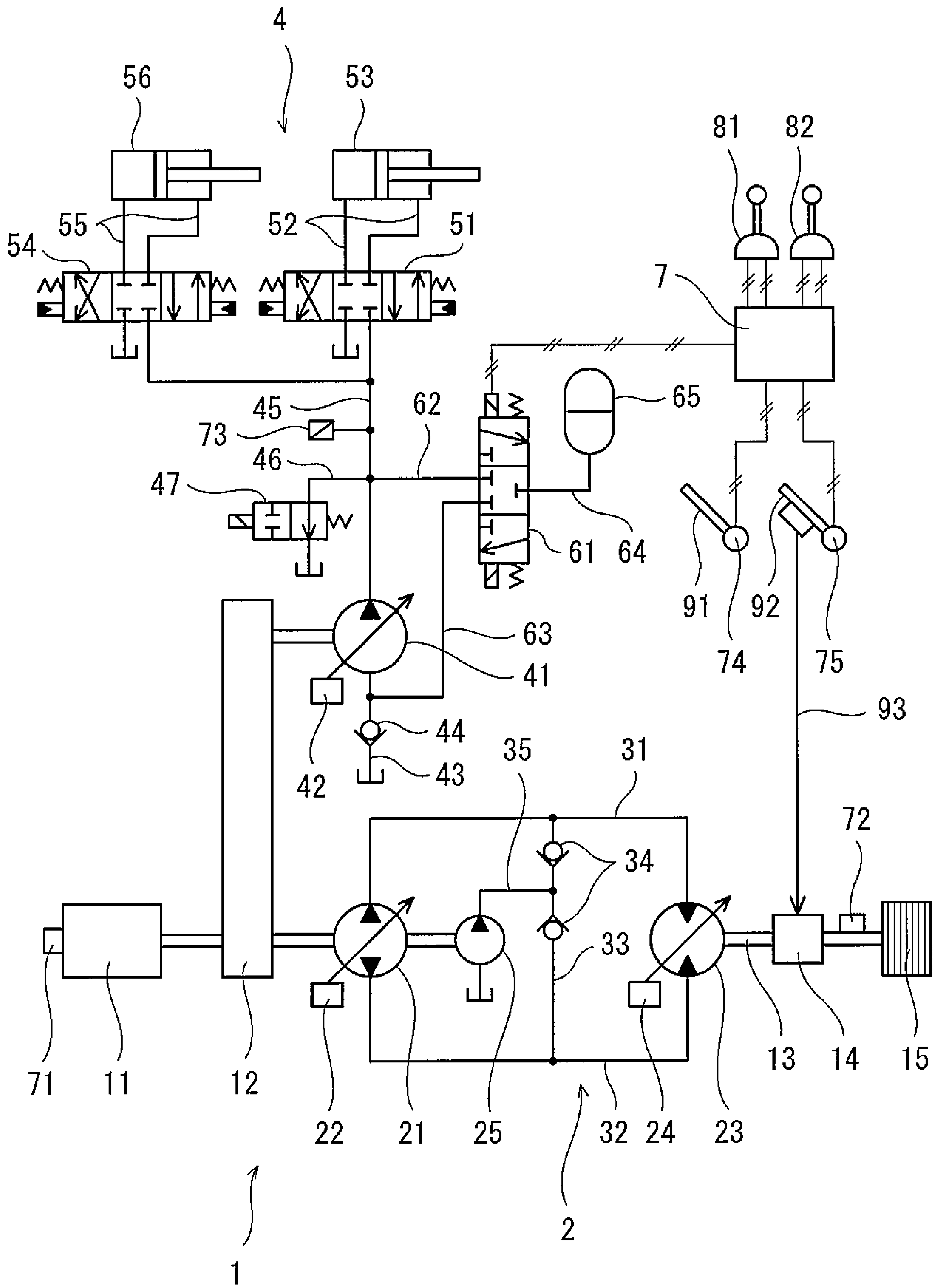
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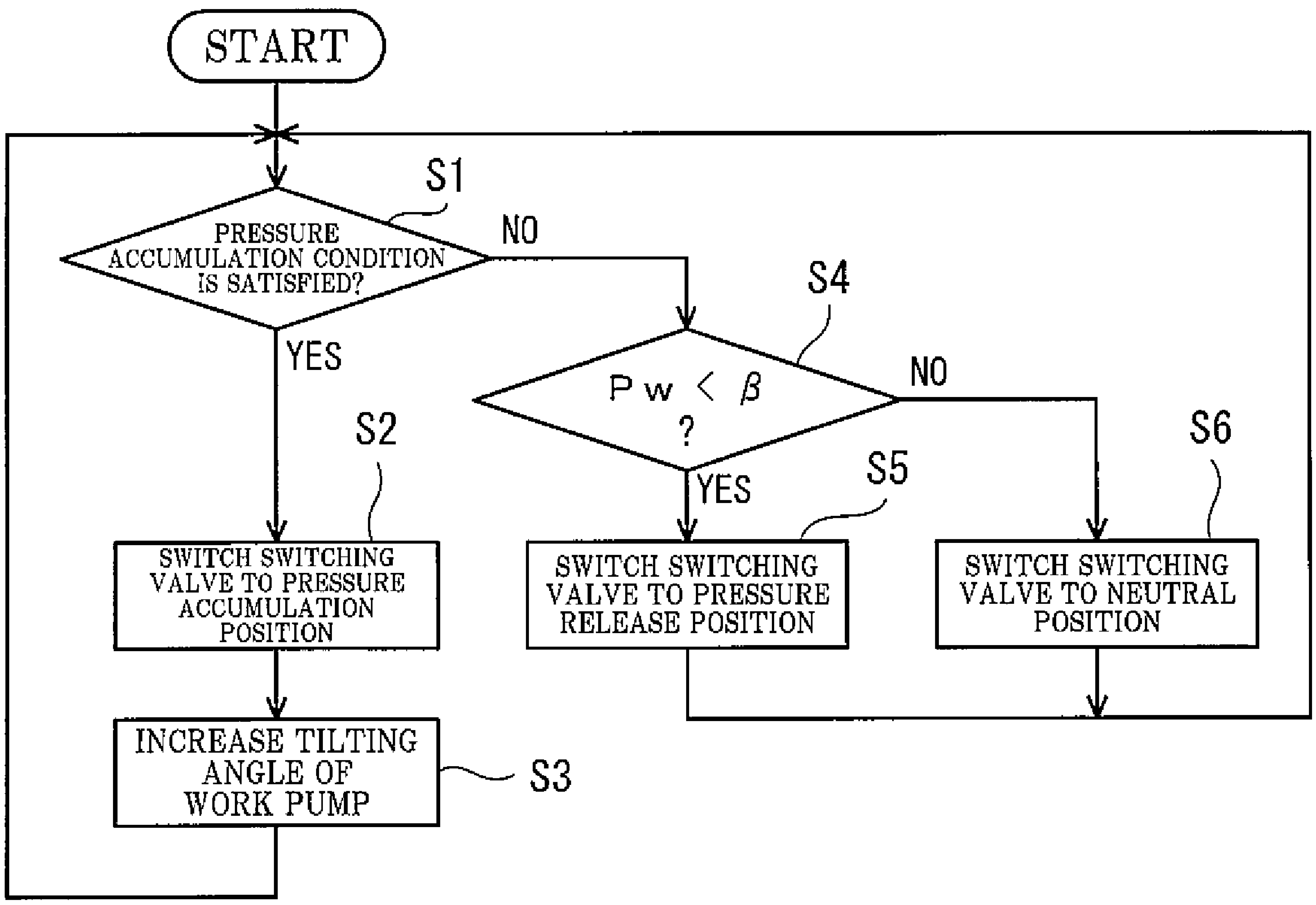
Fig.1


START
S1
PRESSURE ACCUMULATION CONDITION IS SATISFIED?
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SWITCH SWITCHING VALVE TO PRESSURE ACCUMULATION POSITION
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SWITCH SWITCHING VALVE TO PRESSURE RELEASE POSITION
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SWITCH SWITCHING VALVE TO NEUTRAL POSITION
INCREASE TILTING ANGLE OF WORK PUMP
S3

Fig.2

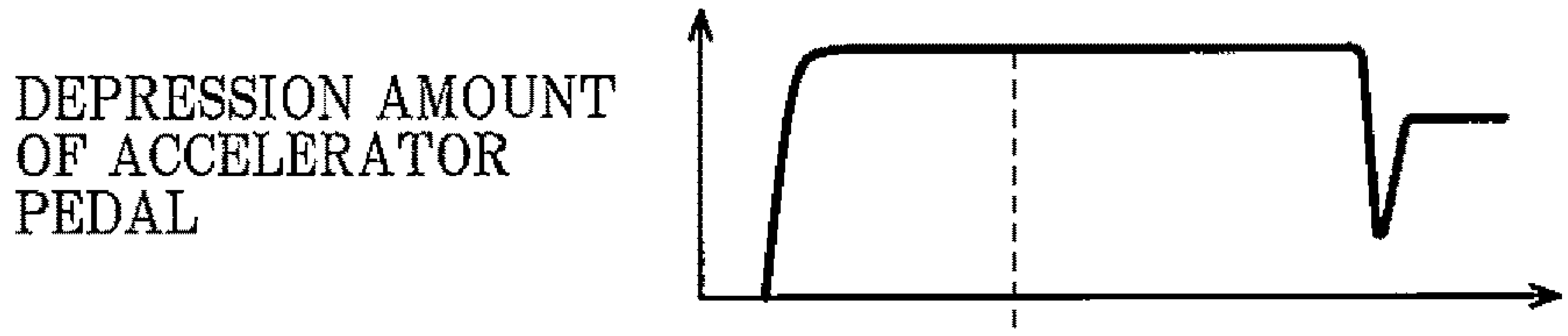

Fig.3A

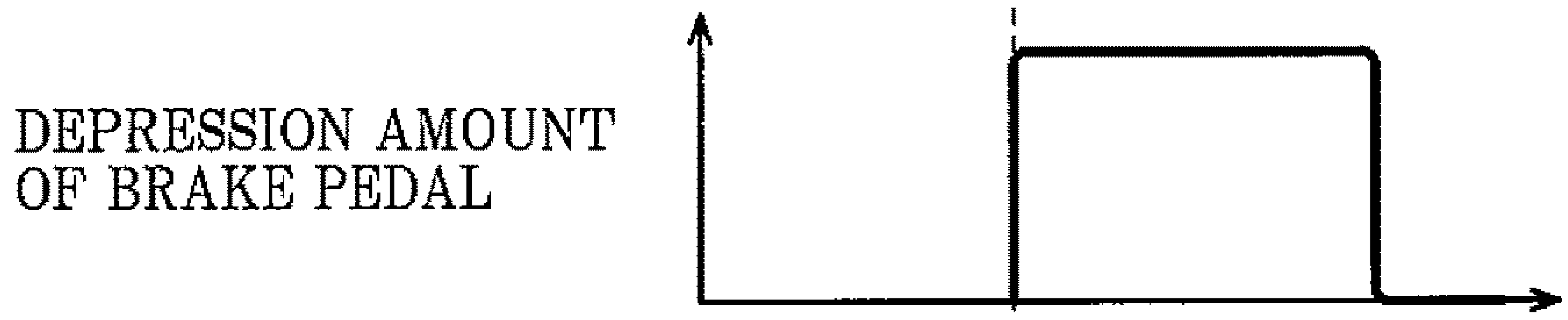

Fig.3B

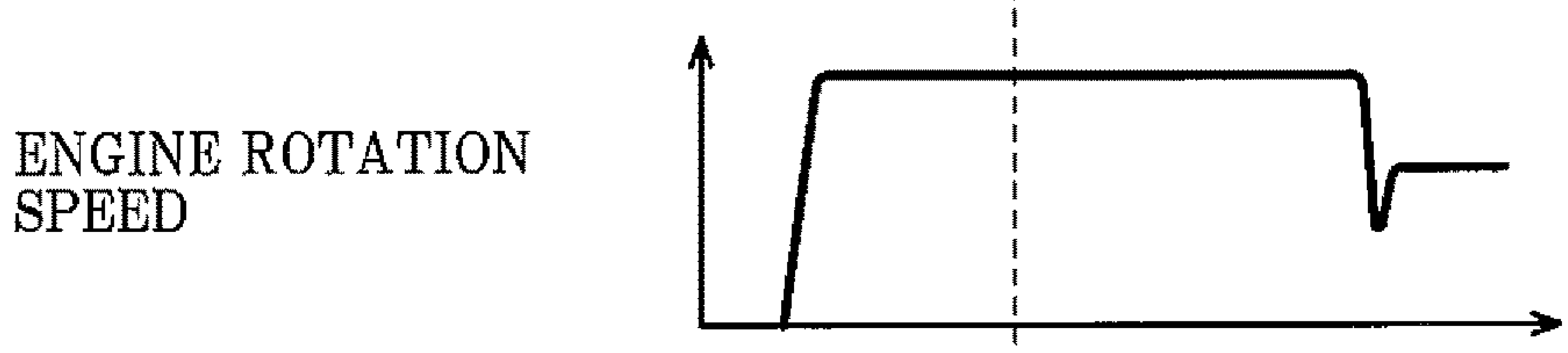

Fig.3C

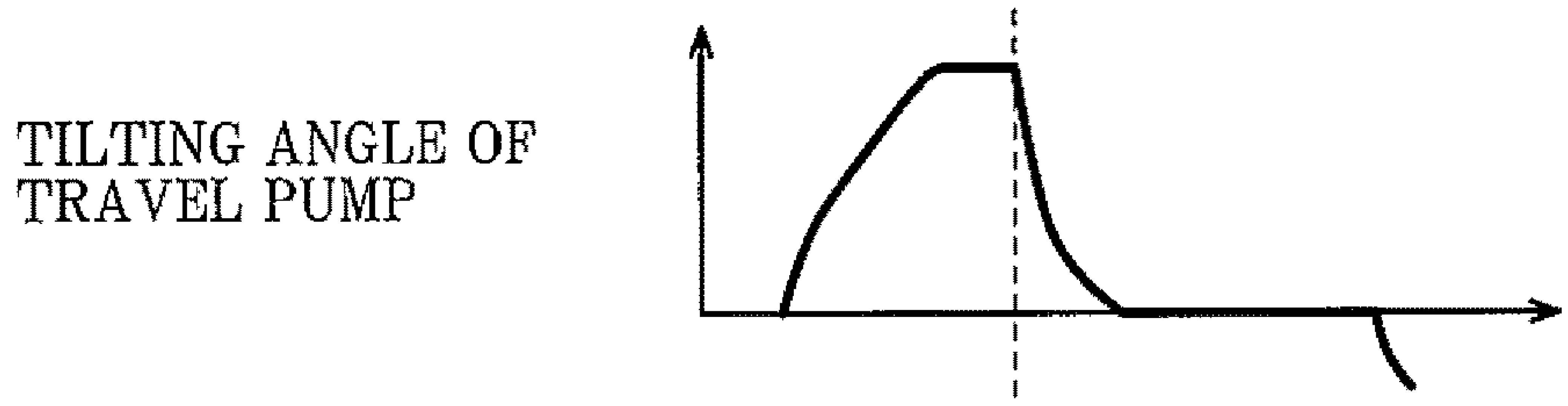

Fig.3D

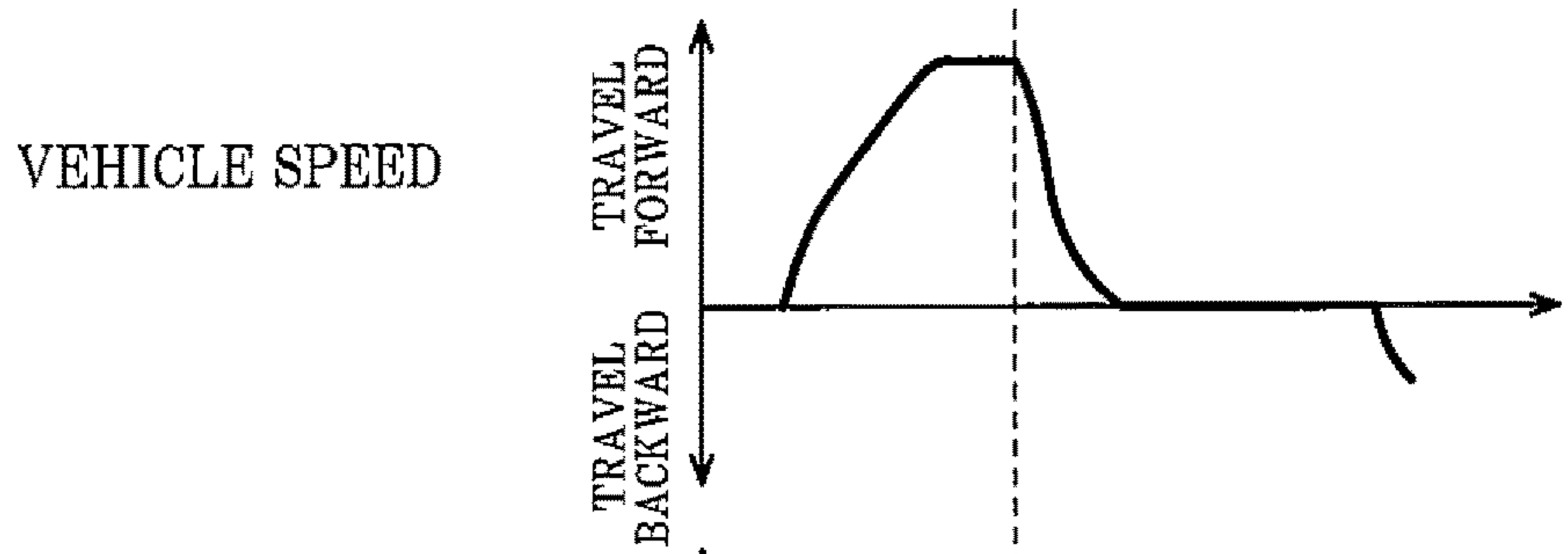

Fig.3E

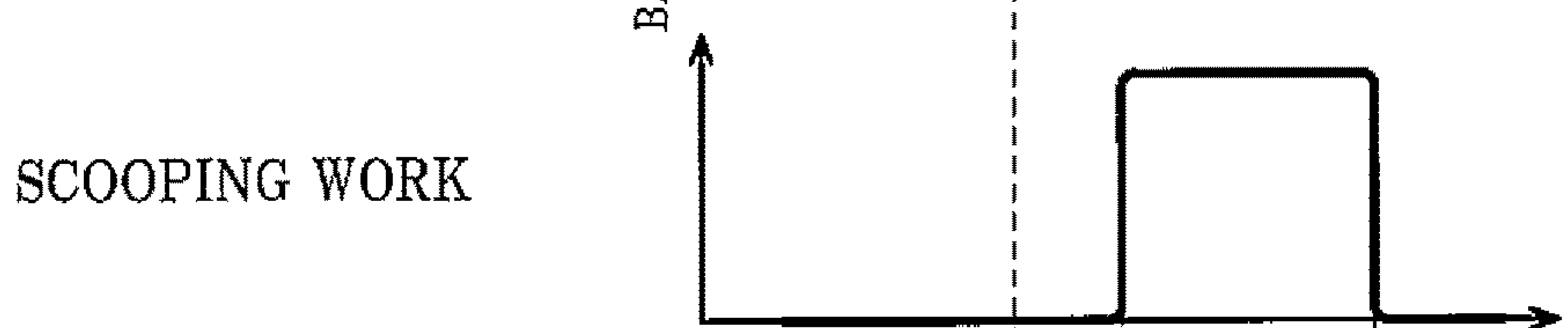

Fig.3F

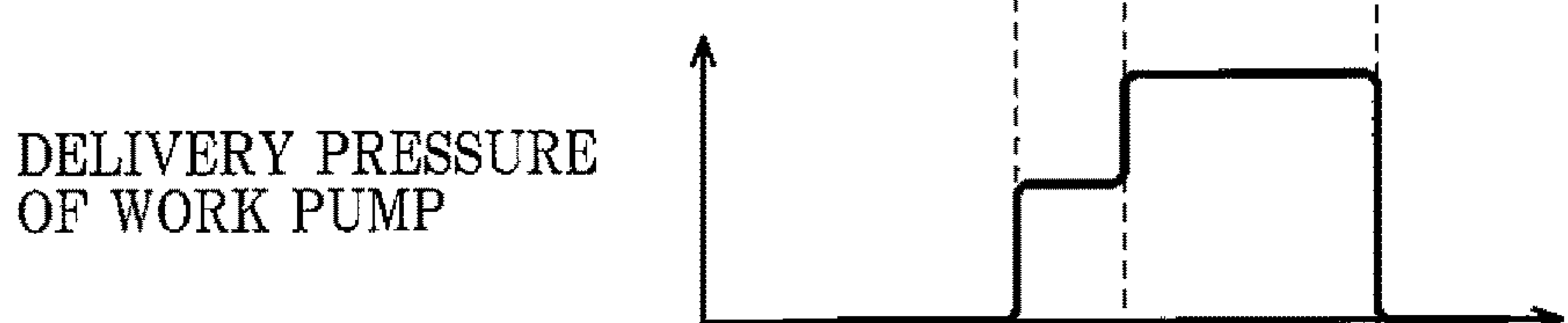

Fig.3G

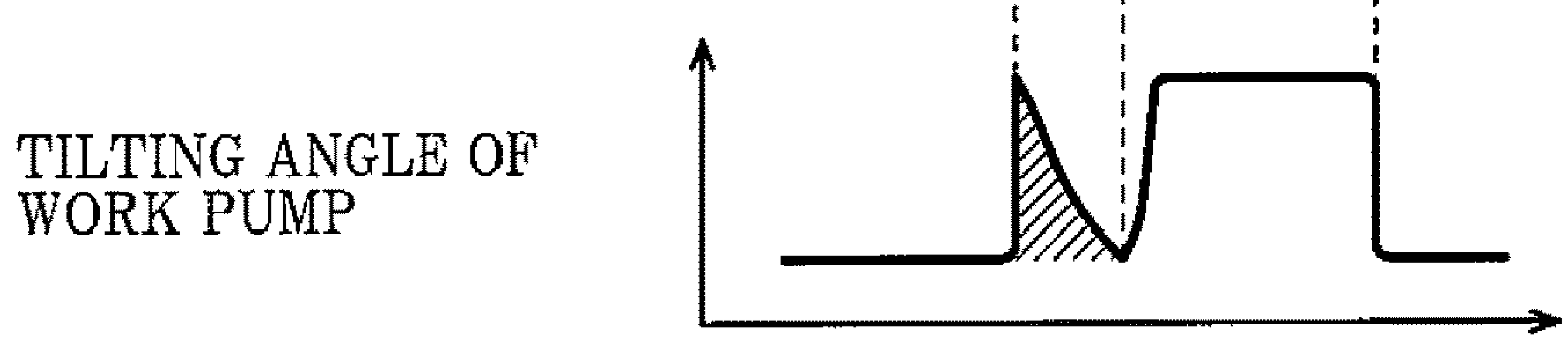

Fig.3H

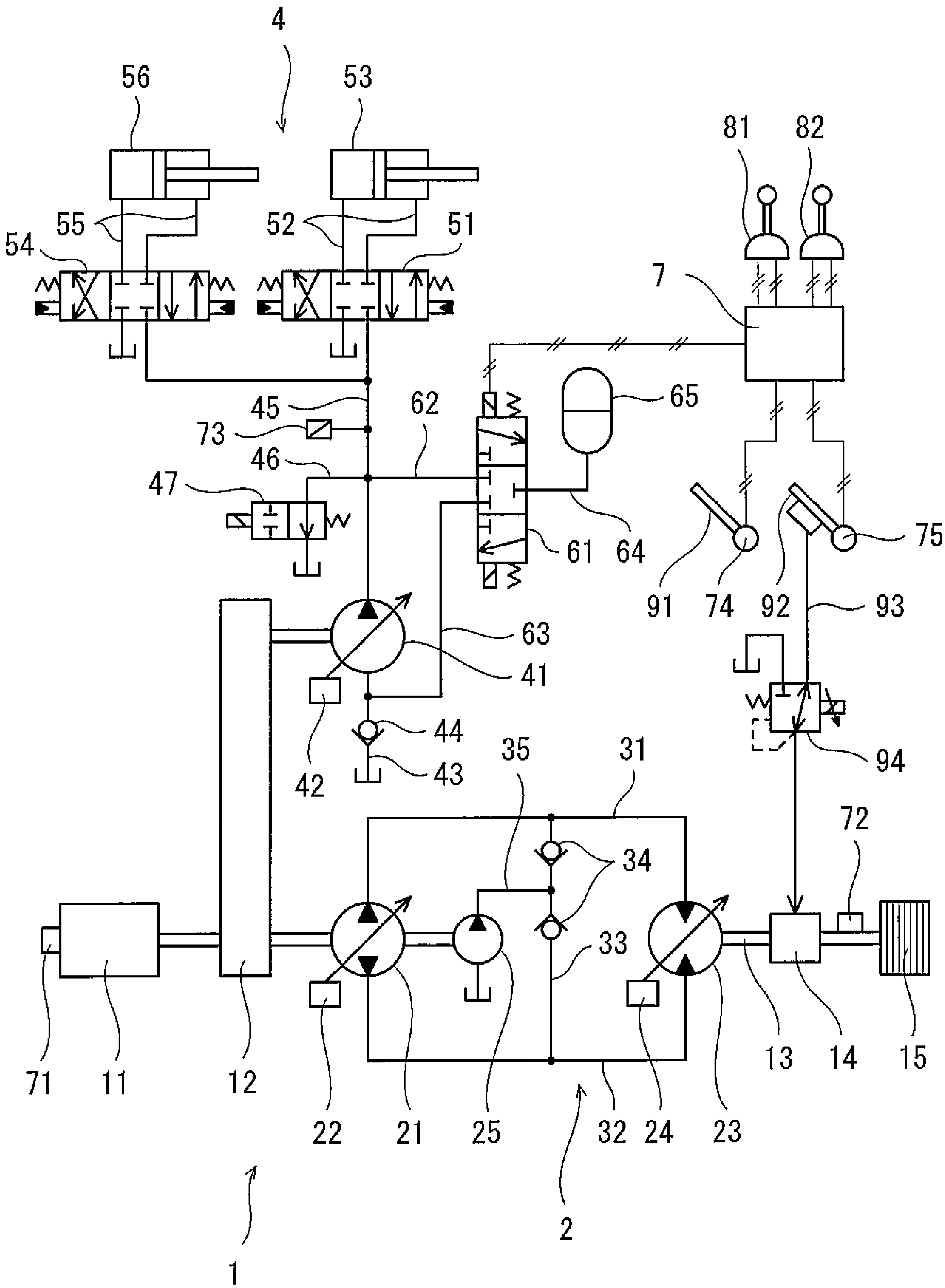
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Fig.4

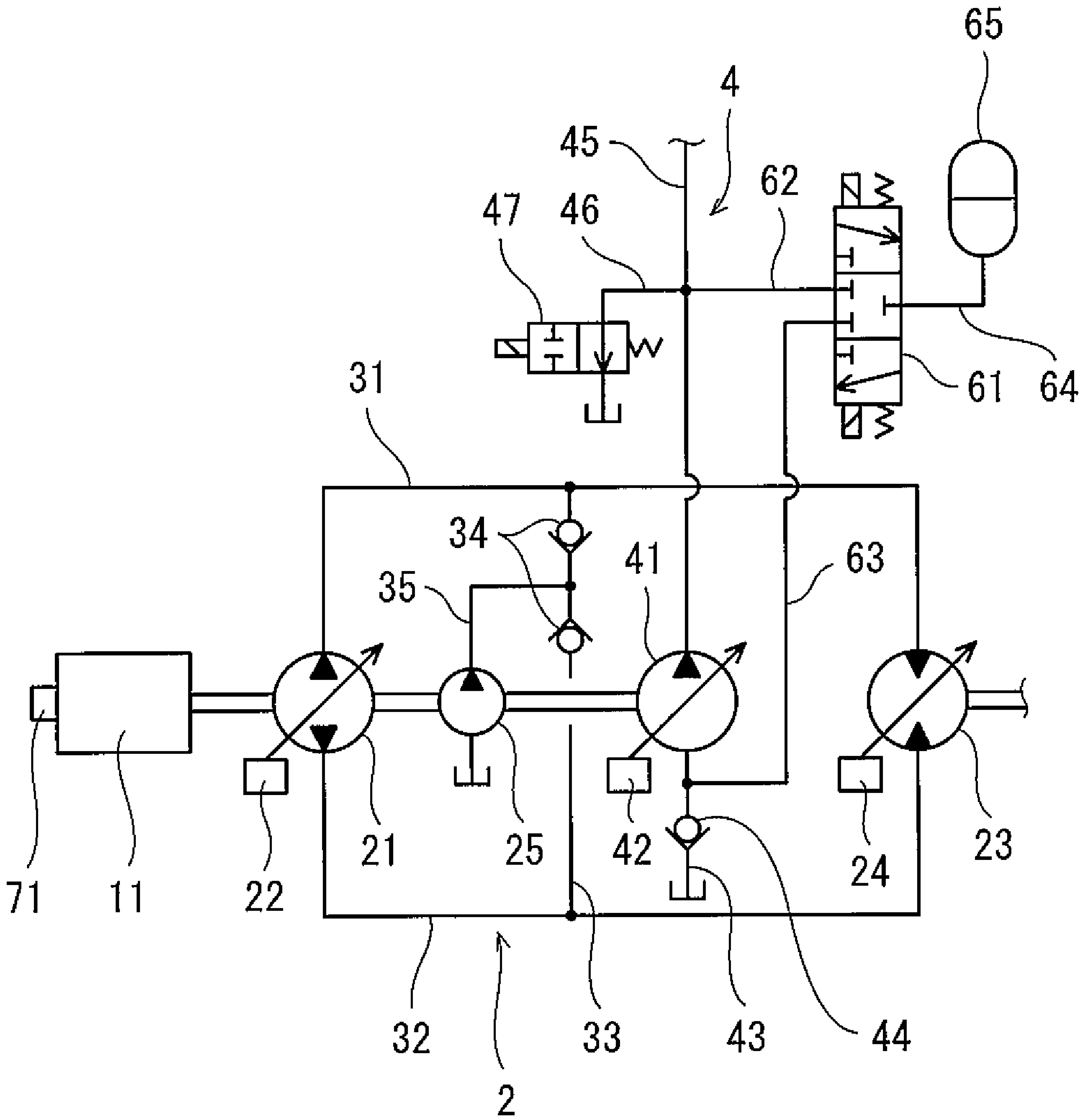
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Fig.5

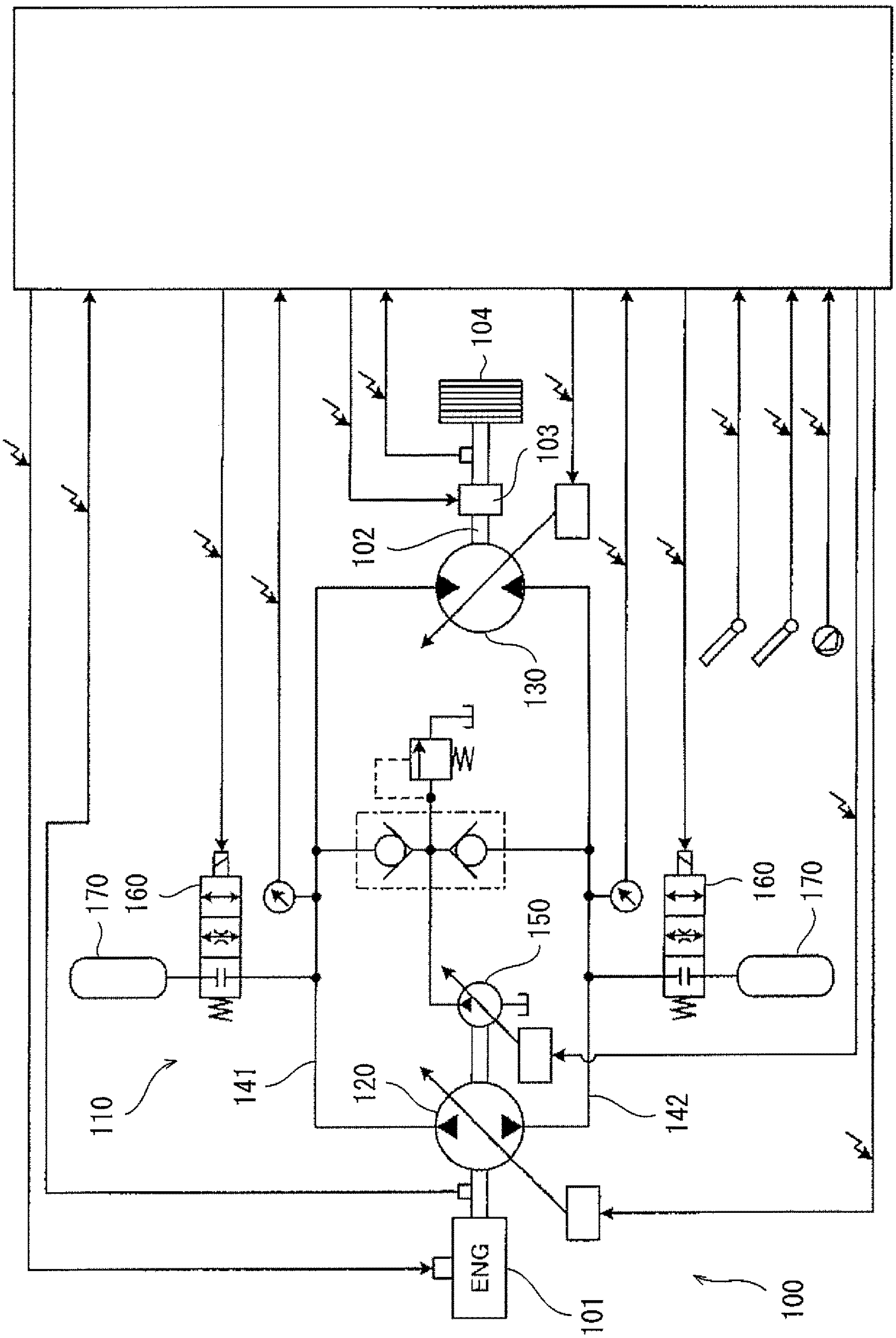

Fig.6

HYDRAULIC SYSTEM OF CONSTRUCTION MACHINE

TECHNICAL FIELD

The present invention relates to a hydraulic system of a construction machine.

BACKGROUND ART

Among construction machines, such as wheel loaders and forklifts, there are those mounted with a hydraulic system that includes: a travel circuit that forms a hydraulic static transmission (HST) between an engine and traveling means, such as wheels or crawlers; and a work circuit for performing work, such as scooping work or lifting work.

For example, Patent Literature 1 discloses a hydraulic system **100** of a construction machine, which includes a travel circuit **110** as shown in FIG. **6**. The travel circuit **110** includes: a travel pump **120**, which is driven by an engine **101**; and a travel motor **130**, which rotates a travel drive shaft **102**. The travel pump **120** is connected to the travel motor **130** by a pair of supply/discharge lines **141** and **142**, such that a closed loop is formed. The supply/discharge lines **141** and **142** are connected to a charge pump **150**.

The travel pump **120** is an over-center pump. When the construction machine travels forward, hydraulic oil is supplied to the travel motor **130** through one of the supply/discharge lines **141** and **142**, and when the construction machine travels backward, the hydraulic oil is supplied to the travel motor **130** through the other one of the supply/discharge lines **141** and **142**. The travel drive shaft **102** transmits torque from the travel motor **130** to a wheel **104**. The travel drive shaft **102** is provided with a mechanical brake **103**.

In addition, the hydraulic system **100** is configured to be able to regenerate kinetic energy during decelerating travel. Specifically, accumulators **170** are connected to the pair of supply/discharge lines **141** and **142**, respectively, via switching valves **160**. Pressurized oil discharged from the travel motor **130** during decelerating forward travel, and pressurized oil discharged from the travel motor **130** during decelerating backward travel, are separately accumulated in these accumulators **170**, respectively. The pressurized oil accumulated in the accumulator **170** during decelerating forward travel is utilized when the construction machine travels backward next time, and the pressurized oil accumulated in the accumulator **170** during decelerating backward travel is utilized when the construction machine travels forward next time.

CITATION LIST

Patent Literature

PTL 1: Japanese Laid-Open Patent Application Publication No. 2014-109329

SUMMARY OF INVENTION

Technical Problem

However, the hydraulic system **100** shown in FIG. **6** requires two accumulators **170** for regenerating kinetic energy during decelerating travel. This causes high cost. Moreover, when accumulating the pressurized oil from one of the supply/discharge lines **141** and **142** into the accumulator **170**, the hydraulic oil in a corresponding amount needs to be charged from the charge pump **150** to the other one of the supply/discharge lines **141** and **142**.

Furthermore, in the hydraulic system **100** shown in FIG. **6**, since the accumulator **170** is connected to each of the supply/discharge lines **141** and **142**, braking force is limited by the setting pressure of the accumulator **170**, and there is a case where only by the accumulation of the pressurized oil in the accumulator **170**, sufficient braking force cannot be obtained. Also, the pressurized oil accumulated in the accumulator **170** cannot be utilized in a situation where the delivery pressure of the travel pump **120** becomes higher than the setting pressure of the accumulator **170** (e.g., during rapid acceleration).

In view of the above, an object of the present invention is to provide a hydraulic system of a construction machine, the hydraulic system being capable of regenerating kinetic energy during decelerating travel without using an accumulator in a travel circuit.

Solution to Problem

In order to solve the above-described problems, a hydraulic system of a construction machine according to the present invention includes: a travel motor that rotates a travel drive shaft; a travel pump that is connected to the travel motor such that a closed loop is formed, the travel pump being driven by an engine; a work pump that sucks hydraulic oil from a tank through a suction line provided with a check valve, and supplies the hydraulic oil to a work hydraulic actuator through a delivery line, the work pump being driven by the engine; a switching valve that is connected to the delivery line by a pressure accumulation line, and connected to a part of the suction line downstream of the check valve by a pressure release line; and an accumulator that is connected to the switching valve by a relay line. The switching valve is switched between a neutral position, a pressure accumulation position, and a pressure release position, the neutral position being a position in which the switching valve blocks the pressure accumulation line, the pressure release line, and the relay line, the pressure accumulation position being a position in which the switching valve brings the pressure accumulation line into communication with the relay line, the pressure release position being a position in which the switching valve brings the relay line into communication with the pressure release line.

According to the above configuration, during decelerating travel, since the travel pump functions as a motor, the driving of the work pump is assisted thereby. Accordingly, when the switching valve is switched to the pressure accumulation position, kinetic energy during decelerating travel can be converted into pressurized oil delivered from the work pump, and the pressurized oil can be accumulated in the accumulator. On the other hand, when the switching valve is switched to the pressure release position, the pressure at the suction side of the work pump increases. As a result, motive power required for driving the work pump decreases, and thereby energy consumption is reduced. Through such a cycle, kinetic energy during decelerating travel is regenerated. Since the accumulator is provided in a work circuit including the work pump, kinetic energy during decelerating travel can be regenerated without using an accumulator in a travel circuit.

The construction machine may be a wheel loader. The above hydraulic system may further include: a controller that controls the switching valve; an accelerator pedal that receives an acceleration command; a mechanical brake provided on the travel drive shaft; a brake pedal that receives a brake operation for the mechanical brake; a vehicle speed detector that detects a vehicle speed; and a delivery pressure detector that detects a delivery pressure of the work pump. The controller may: when a pressure accumulation condition is satisfied, switch the switching valve to the pressure accumulation position, the pressure accumulation condition being a condition that the accelerator pedal and the brake pedal are depressed concurrently and the vehicle speed detected by the vehicle speed detector is higher than a first threshold; and when the pressure accumulation condition is not satisfied, if the delivery pressure of the work pump, which is detected by the delivery pressure detector, is higher than a second threshold, switch the switching valve to the pressure release position, whereas if the delivery pressure of the work pump is lower than the second threshold, switch the switching valve to the neutral position. When the wheel loader performs the work of scooping a material to be carried, the wheel loader first travels to the vicinity of the material to be carried, and stops. Then, the wheel loader performs the scooping work with a bucket and a boom. When the wheel loader stops traveling, the brake pedal is depressed with the accelerator pedal kept depressed in order not to decrease the engine rotation speed in preparation for the scooping work performed thereafter. In light of this, if the pressure accumulation condition is defined as a condition that the accelerator pedal and the brake pedal are depressed concurrently and the vehicle speed is higher than the first threshold, it becomes possible to accumulate pressurized oil in the accumulator by efficiently utilizing a situation where the work pump is driven at a high engine rotation speed.

The above hydraulic system may further include a boom operation device and a bucket operation device, each of which includes an operating lever. The second threshold may be a value that is higher than the delivery pressure of the work pump when the operating lever of the boom operation device and the operating lever of the bucket operation device are in a neutral state. According to this configuration, when the work pump is in a standby state, the accumulator is in a pressure-releasing state. This consequently makes it possible to prevent the engine rotation speed from becoming excessively high.

The work pump may be a variable displacement pump. The above hydraulic system may further include a regulator that adjusts a tilting angle of the work pump. When the pressure accumulation condition is satisfied, the controller may switch the switching valve to the pressure accumulation position, and control the regulator such that the tilting angle of the work pump increases. According to this configuration, the braking force when the pressure accumulation condition is satisfied can be increased.

The above hydraulic system may further include a solenoid proportional valve provided on a signal pressure line that leads a signal pressure corresponding to a depression amount of the brake pedal to the mechanical brake from a brake operation device including the brake pedal, the solenoid proportional valve being capable of decreasing the signal pressure. The controller may control the solenoid proportional valve such that a braking force of the mechanical brake when the pressure accumulation condition is satisfied is less than the braking force of the mechanical brake when the pressure accumulation condition is not satisfied. This configuration makes it possible to suppress the overall braking force from becoming excessively high due to the pressurized oil being accumulated in the accumulator.

Advantageous Effects of Invention

The present invention makes it possible to regenerate kinetic energy during decelerating travel without using an accumulator in a travel circuit.

BRIEF DESCRIPTION OF DRAWINGS

FIG. **1** shows a schematic configuration of a hydraulic system of a construction machine according to one embodiment of the present invention.

FIG. **2** is a flowchart of control performed by a controller.

FIG. **3**A to FIG. **3**H are charts showing temporal changes in the depression amount of an accelerator pedal, the depression amount of a brake pedal, an engine rotation speed, the tilting angle of a travel pump, a vehicle speed, scooping work, the delivery pressure of a work pump, and the tilting angle of the work pump, respectively.

FIG. **4** shows a schematic configuration of the hydraulic system according to a variation.

FIG. **5** shows a schematic configuration of a part of the hydraulic system according to another variation.

FIG. **6** shows a schematic configuration of a conventional hydraulic system of a construction machine.

DESCRIPTION OF EMBODIMENTS

FIG. **1** shows a hydraulic system **1** of a construction machine according to one embodiment of the present invention. In the present embodiment, the construction machine is a wheel loader including a wheel **15** as traveling means. Alternatively, the construction machine may be, for example, a forklift, a compact truck loader, or a crawler carrier. In a case where the construction machine is a compact truck loader or a crawler carrier, the traveling means is a crawler.

The hydraulic system **1** installed in the construction machine includes: an engine **11**; a travel circuit **2**, which forms a hydraulic static transmission (HST) between the engine **11** and the wheel **15**; and a work circuit **4** for performing, for example, scooping work.

The travel circuit **2** includes: a travel pump **21**, which is driven by the engine **11**; and a travel motor **23**, which rotates a travel drive shaft **13**. The travel pump **21** is connected to the travel motor **23** by a pair of supply/discharge lines **31** and **32**, such that a closed loop is formed.

In the present embodiment, the output shaft of the engine **11** is coupled to the rotating shaft of the travel pump **21** via a gearbox **12**. The output shaft of the engine **11** is also coupled to the rotating shaft of a work pump **41** via the gearbox **12**. The work pump **41** will be described below.

The travel pump **21** is an over-center pump. When the construction machine travels forward, hydraulic oil is supplied to the travel motor **23** through one of the supply/discharge lines **31** and **32**, and when the construction machine travels backward, the hydraulic oil is supplied to the travel motor **23** through the other one of the supply/discharge lines **31** and **32**. The travel drive shaft **13** transmits torque from the travel motor **23** to the wheel **15**. The travel drive shaft **13** is provided with a mechanical brake **14**.

The mechanical brake **14** is configured to press a wear component, such as a pad or lining, against a disc or drum that rotates together with the travel drive shaft **13**, thereby applying braking force to the travel drive shaft **13**. To be more specific, the mechanical brake **14** includes brake cylinders provided for respective wheels. When a brake pedal **92**, which will be described below, is depressed, pressurized oil is generated in a master cylinder. The generated pressurized oil is led to each brake cylinder, and consequently, the wear component is pressed against the disc or drum.

The supply/discharge lines **31** and **32** are connected to each other by a bridging passage **33**. The bridging passage **33** is provided with a pair of check valves **34**, which are directed opposite to each other. A part of the bridging passage **33** between the check valves **34** is connected to a charge pump **25** by a charge line **35**. Although not illustrated, a relief line is branched off from the charge line **35**, and the relief line is provided with a relief valve.

The rotating shaft of the charge pump **25** is coupled to the output shaft of the engine **11** via the rotating shaft of the travel pump **21** and the gearbox **12**. The charge pump **25** is driven by the engine **11**.

The travel pump **21** is a variable displacement pump whose tilting angle is changeable. In the present embodiment, the travel pump **21** is a swash plate pump whose tilting angle is defined by the angle of its swash plate. Alternatively, the travel pump **21** may be a bent axis pump whose tilting angle is defined by the angle of its tilted axis. The tilting angle of the travel pump **21** is adjusted by a regulator **22**.

In the present embodiment, the regulator **22** moves in accordance with an electrical signal. Alternatively, the regulator **22** may move in accordance with a hydraulic pilot pressure or a manual lever. For example, the regulator **22** may electrically change the hydraulic pressure applied to a servo piston coupled to the swash plate of the travel pump **21**, or may be an electric actuator coupled to the swash plate of the travel pump **21**.

The travel motor **23** is a variable displacement motor whose tilting angle is changeable. In the present embodiment, the travel motor **23** is a swash plate motor whose tilting angle is defined by the angle of its swash plate. Alternatively, the travel motor **23** may be a bent axis motor whose tilting angle is defined by the angle of its tilted axis. The tilting angle of the travel motor **23** is adjusted by a regulator **24**.

In the present embodiment, the regulator **24** moves in accordance with an electrical signal. Alternatively, the regulator **24** may move in accordance with a hydraulic pilot pressure. For example, the regulator **24** may electrically change the hydraulic pressure applied to a servo piston coupled to the swash plate of the travel motor **23**, or may be an electric actuator coupled to the swash plate of the travel motor **23**.

The regulators **22** and **24** are controlled by a controller **7**. It should be noted that FIG. **1** shows only part of signal lines for simplifying the drawing. For example, the controller **7** is a computer including a CPU and memories such as a ROM and RAM. The CPU executes a program stored in the ROM.

An accelerator pedal **91** and the brake pedal **92** are provided in an operator cab that is not shown. The accelerator pedal **91** receives an acceleration command regarding the engine rotation speed, and the brake pedal **92** receives a brake operation for the mechanical brake **14**.

The mechanical brake **14** is connected, by a signal pressure line **93**, to a brake operation device including the brake pedal **92**. The brake operation device outputs a signal pressure corresponding to a depression amount of the brake pedal **92**. That is, the signal pressure outputted from the brake operation device increases in accordance with increase in the depression amount of the brake pedal **92**. The signal pressure outputted from the brake operation device is led to the mechanical brake **14** through the signal pressure line **93**.

A depression amount θA of the accelerator pedal **91** is detected by a first depression amount detector **74**. A depression amount θB of the brake pedal **92** is detected by a second depression amount detector **75**. The first depression amount detector **74** and the second depression amount detector **75** are, for example, potentiometers.

The controller **7** is electrically connected to the first depression amount detector **74** and the second depression amount detector **75**. The controller **7** is also electrically connected to a rotation speed detector **71**, which detects the engine rotation speed. The controller **7** is further electrically connected to a vehicle speed detector **72**, which detects a vehicle speed V. In the present embodiment, the vehicle speed detector **72** detects the rotation speed of the travel drive shaft **13** as the vehicle speed V.

The controller **7** controls the engine **11**, such that the engine rotation speed detected by the rotation speed detector **71** changes in accordance with the depression amount θA of the accelerator pedal **91**, which is detected by the first depression amount detector **74**, and the vehicle speed V, which is detected by the vehicle speed detector **72**. For example, when the vehicle speed V is lower than a particular value, the engine rotation speed of the engine **11** is increased to a predetermined engine rotation speed in accordance with increase in the depression amount θA of the accelerator pedal **91**, and when the vehicle speed V is higher than or equal to the particular value, the engine rotation speed of the engine **11** is kept at a substantially constant rotation speed.

Further, in a case where only the accelerator pedal **91** is depressed, the controller **7** controls the regulator **22** for the travel pump **21** and the regulator **24** for the travel motor **23** based on the depression amount θA of the accelerator pedal **91**. For example, the controller **7** controls the regulator **22** for the travel pump **21**, such that the tilting angle of the travel pump **21** increases in accordance with increase in the depression amount θA of the accelerator pedal **91**.

On the other hand, when the brake pedal **92** is depressed with the accelerator pedal **91** kept depressed, the controller **7** controls the regulator **22** for the travel pump **21** and the regulator **24** for the travel motor **23** based on the depression amount θB of the brake pedal **92**. For example, the controller **7** controls the regulator **22** for the travel pump **21**, such that the tilting angle of the travel pump **21** decreases in accordance with increase in the depression amount θB of the brake pedal **92**.

The work circuit **4** includes: the work pump **41**, which is driven by the engine **11**; and a boom cylinder **53** and a bucket cylinder **56**, which serve as work hydraulic actuators. The boom cylinder **53** swings an unshown boom, and the bucket cylinder **56** swings an unshown bucket.

The work pump **41** is connected to a tank by a suction line **43**, and to a boom control valve **51** and a bucket control valve **54** by a delivery line **45**. The boom control valve **51** is connected to the boom cylinder **53** by a pair of supply/discharge lines **52**, and the bucket control valve **54** is connected to the bucket cylinder **56** by a pair of supply/discharge lines **55**. That is, the work pump **41** sucks the hydraulic oil from the tank through the suction line **43**, supplies the hydraulic oil to the boom cylinder **53** through the delivery line **45**, the boom control valve **51**, and one of the supply/discharge lines **52**, and supplies the hydraulic oil to the bucket cylinder **56** through the delivery line **45**, the bucket control valve **54**, and one of the supply/discharge lines **55**.

The work pump **41** is a variable displacement pump whose tilting angle is changeable. In the present embodiment, the work pump **41** is a swash plate pump. Alternatively, the work pump **41** may be a bent axis pump. The tilting angle of the work pump **41** is adjusted by a regulator **42**. It should be noted that the minimum delivery flow rate of the work pump **41** is set to be greater than zero.

A delivery pressure Pw of the work pump **41** is kept to be lower than or equal to a relief pressure by an unshown relief valve. An unloading line **46** is branched off from the delivery line **45**, and the unloading line **46** is provided with an unloading valve **47**.

In the present embodiment, the regulator **42** moves in accordance with an electrical signal. Alternatively, the regulator **24** may move in accordance with a hydraulic pilot pressure. For example, the regulator **42** may electrically change the hydraulic pressure applied to a servo piston coupled to the swash plate of the work pump **41**, or may be an electric actuator coupled to the swash plate of the work pump **41**.

A boom operation device **81** and a bucket operation device **82** are provided in the operator cab, which is not shown. The boom operation device **81** includes an operating lever that receives a boom operation, and outputs a boom operation signal corresponding to an inclination angle of the operating lever. That is, the boom operation signal outputted from the boom operation device **81** increases in accordance with increase in the inclination angle (i.e., operating amount) of the operating lever. Similarly, the bucket operation device **82** includes an operating lever that receives a bucket operation, and outputs a bucket operation signal corresponding to an inclination angle of the operating lever.

In the present embodiment, each of the boom operation device **81** and the bucket operation device **82** is an electrical joystick that outputs an electrical signal as an operation signal. The boom operation signal outputted from the boom operation device **81**, and the bucket operation signal outputted from the bucket operation device **82**, are inputted to the controller **7**. The controller **7** controls the boom control valve **51** via an unshown pair of solenoid proportional valves, such that the opening area of the boom control valve **51** is adjusted to an opening area corresponding to the boom operation signal. The controller **7** also controls the bucket control valve **54** via an unshown pair of solenoid proportional valves, such that the opening area of the bucket control valve **54** is adjusted to an opening area corresponding to the bucket operation signal.

The controller **7** further controls the regulator **42** and the unloading valve **47**, such that the tilting angle of the work pump **41** increases, and the opening area of the unloading valve **47** decreases, in accordance with increase in the boom operation signal and/or the bucket operation signal.

It should be noted that each of the boom operation device **81** and the bucket operation device **82** may be a pilot operation valve that outputs a pilot pressure as an operation signal. In this case, pilot ports of the boom control valve **51** are connected by pilot lines to the boom operation device **81**, which is a pilot operation valve, and pilot ports of the bucket control valve **54** are connected by pilot lines to the bucket operation device **82**, which is a pilot operation valve. Further, in a case where the boom operation device **81** is a pilot operation valve, the pilot lines between the boom control valve **51** and the boom operation device **81** are each provided with a pressure detector, and a pilot pressure (a boom operation signal) detected by the pressure detector is inputted to the controller **7**. The same is true in a case where the bucket operation device **82** is a pilot operation valve. Alternatively, the boom control valve **51** and the bucket control valve **54** may be solenoid pilot valves.

The present embodiment further adopts a configuration for regenerating kinetic energy during decelerating travel by utilizing the work pump **41**.

Specifically, the suction line **43** of the work pump **41** is provided with a check valve **44**. A part of the suction line **43** downstream of the check valve **44** is connected to a switching valve **61** by a pressure release line **63**. Also, the switching valve **61** is connected to the delivery line **45** by a pressure accumulation line **62**, and to an accumulator **65** by a relay line **64**.

The switching valve **61** is switched between a neutral position, a pressure accumulation position (upper position in FIG. **1**), and a pressure release position (lower position in FIG. **1**). When the switching valve **61** is in the neutral position, the switching valve **61** blocks the pressure accumulation line **62**, the pressure release line **63**, and the relay line **64**. When the switching valve **61** is in the pressure accumulation position, the switching valve **61** blocks the pressure release line **63**, and brings the pressure accumulation line **62** into communication with the relay line **64**. When the switching valve **61** is in the pressure release position, the switching valve **61** blocks the pressure accumulation line **62**, and brings the relay line **64** into communication with the pressure release line **63**.

The switching valve **61** is controlled by the controller **7**. The controller **7** is also electrically connected to a delivery pressure detector **73**, which detects the delivery pressure Pw of the work pump **41**. FIG. **2** is a flowchart of control of the switching valve **61**, which is performed by the controller **7**.

First, the controller **7** determines whether or not a pressure accumulation condition is satisfied (step S**1**). When the pressure accumulation condition is satisfied (YES in step S**1**), the controller **7** switches the switching valve **61** to the pressure accumulation position (step S**2**).

The pressure accumulation condition is a condition that the accelerator pedal **91** and the brake pedal **92** are depressed concurrently and the vehicle speed V detected by the vehicle speed detector **72** is higher than a first threshold α. The controller **7** determines whether or not the accelerator pedal **91** is depressed by comparing the depression amount θA of the accelerator pedal **91**, which is detected by the first depression amount detector **74**, with a first setting value $\theta 1$, and determines whether or not the brake pedal **92** is depressed by comparing the depression amount θB of the brake pedal **92**, which is detected by the second depression amount detector **75**, with a second setting value $\theta 2$. The first threshold α is an index for determining whether or not the wheel loader is traveling. The first threshold α is, for example, about 1 km/h.

When switching the switching valve **61** to the pressure accumulation position, the controller **7** controls the regulator **42** such that the tilting angle of the work pump **41** increases (step S**3**). It should be noted that step S**3** may be eliminated. Also, when switching the switching valve **61** to the pressure accumulation position, the controller **7** may control the regulator **42** such that the amount of increase in the tilting angle of the work pump **41** decreases in accordance with decrease in the vehicle speed V.

On the other hand, when the pressure accumulation condition is not satisfied (NO in step S**1**), the controller **7** switches the switching valve **61** to the neutral position or the pressure release position based on the delivery pressure Pw of the work pump **41**, which is detected by the delivery pressure detector **73**. To be more specific, in a case where the delivery pressure Pw of the work pump **41** is higher than a second threshold β, the controller **7** switches the switching valve **61** to the pressure release position, whereas in a case where the delivery pressure Pw of the work pump **41** is lower than the second threshold β, the controller **7** switches the switching valve **61** to the neutral position.

The second threshold β is an index for determining whether or not the hydraulic oil is being supplied from the work pump **41** to a work hydraulic actuator (i.e., whether or not work by the work circuit **4** is being performed). For example, the second threshold β is 0.1 to 10 MPa. Desirably, the second threshold β is a value (e.g., 2 to 10 MPa) that is higher than the delivery pressure Pw of the work pump **41** when the operating lever of the boom operation device **81** and the operating lever of the bucket operation device **82** are in a neutral state. The reason for setting the second threshold β to such a value is that if the second threshold β is set to a relatively high value, the accumulator **65** will be in a pressure-releasing state when the work pump **41** is in a standby state. This consequently makes it possible to prevent the engine rotation speed from becoming excessively high.

For example, FIGS. **3**A to **3**H are timing charts for a period from before to after the start of scooping work. When the wheel loader travels to the vicinity of a material to be carried, only the accelerator pedal **91** is depressed. Normally, while the wheel loader is traveling, the boom operation device **81** and the bucket operation device **82** are not operated. Accordingly, the switching valve **61** is kept in the neutral position until the brake pedal **92** is depressed.

When the wheel loader stops after arriving at the vicinity of the material to be carried, the brake pedal **92** is depressed with the accelerator pedal **91** kept depressed. It should be noted that some operator may depress the brake pedal **92** while slightly returning the accelerator pedal **91**. As a result, the tilting angle of the travel pump **21** decreases, and the mechanical brake **14** applies. Consequently, the vehicle speed V decreases. During decelerating travel, since the travel pump **21** functions as a motor, the driving of the work pump **41** is assisted thereby.

Since the brake pedal **92** is depressed with the accelerator pedal **91** kept depressed, the switching valve **61** is switched to the pressure accumulation position, and also, the tilting angle of the work pump **41** increases, causing increase in the delivery flow rate of the work pump **41**. Accordingly, the delivery pressure of the work pump **41** increases to the setting pressure of the accumulator **65**, and the oil delivered from the work pump **41** is accumulated in the accumulator **65**. That is, when the switching valve **61** is switched to the pressure accumulation position, kinetic energy during decelerating travel can be converted into pressurized oil delivered from the work pump **41**, and the pressurized oil can be accumulated in the accumulator **65**.

Thereafter, the scooping work is started, and when the delivery pressure Pw of the work pump **41** has become higher than the second threshold β, the switching valve **61** is switched to the pressure release position, and the pressure at the suction side of the work pump **41** increases. As a result, motive power required for driving the work pump **41** decreases, and thereby energy consumption is reduced.

As described above, in the hydraulic system **1** according to the present embodiment, kinetic energy during decelerating travel is regenerated through a cycle in which pressurized oil is accumulated in the accumulator **65** and then the accumulated pressurized oil is released from the accumulator **65**. Since the accumulator **65** is provided in the work circuit **4**, kinetic energy during decelerating travel can be regenerated without using an accumulator in the travel circuit **2**.

Further, in the present embodiment, the pressure accumulation condition is defined as a condition that the accelerator pedal **91** and the brake pedal **92** are depressed concurrently and the vehicle speed V is higher than the first threshold α. This makes it possible to accumulate pressurized oil in the accumulator **65** by efficiently utilizing a situation where the work pump **41** is driven at a high engine rotation speed immediately before the start of the scooping work.

Moreover, in the present embodiment, when the pressure accumulation condition is satisfied, the tilting angle of the work pump **41** increases. Accordingly, the torque generated by the work pump **41** (which is proportional to the product of the delivery pressure and the delivery capacity of the work pump **41**) increases, which makes it possible to increase the braking force.

Furthermore, in the present embodiment, when the switching valve **61** is switched to the pressure accumulation position, the amount of increase in the tilting angle of the work pump **41** (which is indicated by a hatched area in FIG. **3**H) decreases in accordance with decrease in the vehicle speed V. Accordingly, the torque generated by the work pump **41** can be reduced in accordance with decrease in the vehicle speed V, i.e., in accordance with decrease in kinetic energy. This makes it possible to ease a sensation that the braking force is too strong in the latter half of the deceleration.

OTHER EMBODIMENTS

The present invention is not limited to the above-described embodiment. Various modifications can be made without departing from the scope of the present invention.

For example, as shown in FIG. **4**, the signal pressure line **93** between the mechanical brake **14** and the brake operation device including the brake pedal **92** may be provided with a solenoid proportional valve **94**, which is capable of decreasing the signal pressure outputted from the brake operation device. In this case, the controller **7** controls the solenoid proportional valve **94**, such that the braking force of the mechanical brake **14** when the pressure accumulation condition is satisfied is less than the braking force of the mechanical brake **14** when the pressure accumulation condition is not satisfied. According to this configuration, when the load on the work pump **41** increases, braking force is applied to the travel drive shaft **13** via the travel pump **21** and the travel motor **23**. Accordingly, the amount of wear of the wear components, such as the pads or linings, of the mechanical brake **14** is reduced. Moreover, this configuration makes it possible to suppress the overall braking force from becoming excessively high due to the pressurized oil being accumulated in the accumulator **65**.

As shown in FIG. **5**, the output shaft of the engine **11** may be directly coupled to the rotating shaft of the travel pump **21**. In this case, the rotating shaft of the work pump **41** may be directly coupled to the rotating shaft of the charge pump **25**.

REFERENCE SIGNS LIST

1 hydraulic system
11 engine
13 travel drive shaft
14 mechanical brake
21 travel pump
23 travel motor
41 work pump
42 regulator
43 suction line
44 check valve

45 delivery line
53 boom cylinder (work hydraulic actuator)
56 bucket cylinder (work hydraulic actuator)
61 switching valve
62 pressure accumulation line
63 pressure release line
64 relay line
65 accumulator
7 controller
72 vehicle speed detector
73 delivery pressure detector
81 boom operation device
82 bucket operation device
91 accelerator pedal
92 brake pedal
93 signal pressure line
94 solenoid proportional valve

The invention claimed is:

1. A hydraulic system of a construction machine, comprising:
- a travel motor that rotates a travel drive shaft;
- a travel pump that is connected to the travel motor such that a closed loop is formed, the travel pump being driven by an engine;
- a work pump that sucks hydraulic oil from a tank through a suction line provided with a check valve, and supplies the hydraulic oil to a work hydraulic actuator through a delivery line, the work pump being driven by the engine;
- a switching valve that is connected to the delivery line by a pressure accumulation line, and connected to a part of the suction line downstream of the check valve by a pressure release line; and
- an accumulator that is connected to the switching valve by a relay line, wherein
- the switching valve is switched between a neutral position, a pressure accumulation position, and a pressure release position, the neutral position being a position in which the switching valve blocks the pressure accumulation line, the pressure release line, and the relay line, the pressure accumulation position being a position in which the switching valve brings the pressure accumulation line into communication with the relay line, the pressure release position being a position in which the switching valve brings the relay line into communication with the pressure release line.

2. The hydraulic system of a construction machine according to claim **1**, wherein
- the construction machine is a wheel loader,
- the hydraulic system further comprises:
- a controller that controls the switching valve;
- an accelerator pedal that receives an acceleration command;
- a mechanical brake provided on the travel drive shaft;
- a brake pedal that receives a brake operation for the mechanical brake;
- a vehicle speed detector that detects a vehicle speed; and
- a delivery pressure detector that detects a delivery pressure of the work pump, and
- the controller:
  - when a pressure accumulation condition is satisfied, switches the switching valve to the pressure accumulation position, the pressure accumulation condition being a condition that the accelerator pedal and the brake pedal are depressed concurrently and the vehicle speed detected by the vehicle speed detector is higher than a first threshold; and
  - when the pressure accumulation condition is not satisfied, if the delivery pressure of the work pump, which is detected by the delivery pressure detector, is higher than a second threshold, switches the switching valve to the pressure release position, whereas if the delivery pressure of the work pump is lower than the second threshold, switches the switching valve to the neutral position.

3. The hydraulic system of a construction machine according to claim **2**, further comprising a boom operation device and a bucket operation device, each of which includes an operating lever, wherein
- the second threshold is a value that is higher than the delivery pressure of the work pump when the operating lever of the boom operation device and the operating lever of the bucket operation device are in a neutral state.

4. The hydraulic system of a construction machine according to claim **2**, wherein
- the work pump is a variable displacement pump,
- the hydraulic system further comprises a regulator that adjusts a tilting angle of the work pump, and
- when the pressure accumulation condition is satisfied, the controller switches the switching valve to the pressure accumulation position, and controls the regulator such that the tilting angle of the work pump increases.

5. The hydraulic system of a construction machine according to claim **2**, further comprising a solenoid proportional valve provided on a signal pressure line that leads a signal pressure corresponding to a depression amount of the brake pedal to the mechanical brake from a brake operation device including the brake pedal, the solenoid proportional valve being capable of decreasing the signal pressure, wherein
- the controller controls the solenoid proportional valve such that a braking force of the mechanical brake when the pressure accumulation condition is satisfied is less than the braking force of the mechanical brake when the pressure accumulation condition is not satisfied.

6. The hydraulic system of a construction machine according to claim **3**, wherein
- the work pump is a variable displacement pump,
- the hydraulic system further comprises a regulator that adjusts a tilting angle of the work pump, and
- when the pressure accumulation condition is satisfied, the controller switches the switching valve to the pressure accumulation position, and controls the regulator such that the tilting angle of the work pump increases.

7. The hydraulic system of a construction machine according to claim **3**, further comprising a solenoid proportional valve provided on a signal pressure line that leads a signal pressure corresponding to a depression amount of the brake pedal to the mechanical brake from a brake operation device including the brake pedal, the solenoid proportional valve being capable of decreasing the signal pressure, wherein
- the controller controls the solenoid proportional valve such that a braking force of the mechanical brake when the pressure accumulation condition is satisfied is less than the braking force of the mechanical brake when the pressure accumulation condition is not satisfied.

8. The hydraulic system of a construction machine according to claim **4**, further comprising a solenoid proportional valve provided on a signal pressure line that leads a signal pressure corresponding to a depression amount of the brake pedal to the mechanical brake from a brake operation device including the brake pedal, the solenoid proportional valve being capable of decreasing the signal pressure, wherein

the controller controls the solenoid proportional valve such that a braking force of the mechanical brake when the pressure accumulation condition is satisfied is less than the braking force of the mechanical brake when the pressure accumulation condition is not satisfied.

9. The hydraulic system of a construction machine according to claim **6**, further comprising a solenoid proportional valve provided on a signal pressure line that leads a signal pressure corresponding to a depression amount of the brake pedal to the mechanical brake from a brake operation device including the brake pedal, the solenoid proportional valve being capable of decreasing the signal pressure, wherein

the controller controls the solenoid proportional valve such that a braking force of the mechanical brake when the pressure accumulation condition is satisfied is less than the braking force of the mechanical brake when the pressure accumulation condition is not satisfied.

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